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# A Comparison Of Therapeutic Heating Modalities And Stretching Techniques To Increase Hip Flexion

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A COMPARISON OF THERAPEUTIC HEATING MODALITIES  
AND STRETCHING TECHNIQUES TO  
INCREASE HIP FLEXION

being

A Thesis Presented to the Graduate Faculty  
of the Fort Hays State University in  
Partial Fulfillment of the Requirements for  
the Degree of Master of Science

by

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Chair, Thesis Committee

Approved\_\_\_\_\_  
Chair, Graduate Council

## ABSTRACT

Individuals can positively benefit from increasing flexibility. These benefits include: preventing injury, improving blood flow to soft tissues, improving posture, and decreasing low back pain. Traditionally, stretching is used to increase flexibility. However, stretching in combination with heating modalities have shown to increase flexibility as well. This study was designed to investigate the effect of pulsed shortwave diathermy (PSWD) on hamstring flexibility using static stretch versus proprioceptive neuromuscular facility (PNF) contract relax as compared to superficial heat and static stretch. This study examined 30 college-aged individuals who had 90° or less of hip flexion. Participants were randomly divided into one of three groups: pulsed shortwave diathermy combined with PNF contract relax stretching, pulsed shortwave diathermy combined with static stretching, or moist heat pack combined with static stretching. The participants had a pre-test hip flexion measure followed by a heating and stretching protocol three times a week for five weeks and finished with a post-test measure. There was a significant difference in pre- and post-test scores of flexibility in the PSWD combined with PNF contract relax stretching group ( $t=13.5171$  and  $p<.001$ ), PSWD combined with static stretching group ( $t=12.2241$  and  $p<.001$ ) and moist heat pack combined with static stretching group ( $t=6.4398$  and  $p=.0001$ ). There was a significant difference between post-test scores of flexibility between the PSWD combined with PNF contract relax stretching group and the PSWD combined with static stretching group ( $t=2.4687$  and  $p=.0122$ ) and the PSWD combined with PNF contract relax stretching group and the moist heat pack combined with static stretching group ( $t=3.0917$  and

$p=.0035$ ). There was no significant difference in post-test scores of flexibility in the PSWD combined with static stretching group and the moist heat pack combined with static stretching group ( $t=1.1984$  and  $p=.1247$ ). This study concluded PSWD combined with PNF contract relax stretching technique had the greatest increase in range of motion over a five-week period. In order for athletes to gain maximum range of motion results, athletic trainers should use a combined approach of PSWD application followed by a PNF contract-relax stretching technique.



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## **Chapter I**

### **INTRODUCTION**

Clinicians, in multiple professional areas including athletic training, have been using deep heating modalities to increase tissue extensibility, lessen nerve sensitivity, increase blood flow, increase tissue metabolism, decrease muscle spindle sensitivity to stretch, cause muscle relaxation, and increase tissue flexibility (Draper, Knight, Fujiwara, & Castel, 1999; Hawkes, Draper, Johnson, Diede, & Rigby, 2013; Peres, Draper, Knight, & Ricard, 2002; Taylor, Waring, & Brashear, 1995). There are two forms of thermotherapy: deep and superficial. “Deep thermotherapy is the application of modalities that cause a tissue temperature rise in deep tissues” (Knight & Draper, 2008a, p. 189). Pulsed shortwave diathermy (PSWD) is a modality of deep thermotherapy which until 1999 had been rarely practiced in the clinical setting. Currently it is being used as a deep heating modality, heating tissues at a depth of 3 to 5 cm and causing a 4° C temperature increase within tissues (Garrett, Draper, & Knight, 2000; Peres et al., 2002; Robertson, Ward, & Jung, 2005). Another form of thermotherapy is superficial. “Superficial thermal modalities will heat tissues deeper than 1 cm, but the amount of heating is not enough to evoke the desired therapeutic effects” (Knight & Draper, 2008a, p. 189). Past research has shown tissue temperature must increase 1° C to achieve mild heating and 2° C to 3° C for moderate heating (Hawkes et al., 2013). These type of heating modalities include silicate gel hot packs, whirlpool, and paraffin baths, which cause temperature changes in tissues at a depth of 1 cm (Garrett et al., 2000).

Coaches, athletic trainers, and therapists have traditionally used stretching to restore muscle flexibility, prevent injury, maximize sports performance, regain range of motion (ROM), and alleviate muscle soreness (Feland, Myrer, & Merrill, 2001; Miyahara, Naito, Ogura, Katamoto, & Aoki, 2013; Nakano, Yamabayashi, Scott, & Reid, 2012). The time, duration and magnitude of stretching have been widely debated between researchers, as well as different stretching techniques like static and proprioceptive neuromuscular facilitation (PNF) stretching. Using heat as a modality combined with stretching has shown to increase flexibility and restore range of motion (Draper, Miner, Knight, & Ricard, 2002; Henricson et al. 1984; Nakano et al. 2012). “Increasing the temperature has a positive effect on the ability of the collagen and elastin components within the musculotendinous unit to deform” (Prentice, 2011, p. 180).

### **Problem Statement**

The purpose of this study was to investigate the effect of pulsed shortwave diathermy on hamstring flexibility using static stretch versus proprioceptive neuromuscular facility contract relax as compared to superficial heat and static stretch.

### **Sub Problems**

Within the problem of the study, the following sub-problems were investigated:

1. The difference between pre- and post-test scores for hamstring flexibility after treatment with pulsed shortwave diathermy combined with PNF contract relax stretching.
2. The difference between pre- and post-test scores for hamstring flexibility after treatment with pulsed shortwave diathermy combined with static stretching.



3. The difference between pre- and post-test scores for hamstring flexibility after treatment with a moist heat pack combined with static stretching.

4. The difference between post-test scores for hamstring flexibility after treatment with pulsed shortwave diathermy combined with PNF contract relax stretching versus treatment with a moist heat pack combined with static stretching.

5. The difference between post-test scores for hamstring flexibility after treatment with pulsed shortwave diathermy combined with PNF contract relax stretching versus treatment with pulsed shortwave diathermy combined with static stretching.

6. The difference between post-test scores for hamstring flexibility after treatment with pulsed shortwave diathermy combined with static stretching versus treatment with a moist heat pack combined with static stretching.

### **Definition of Terms**

The following terms were used within the scope of the present study:

**Proprioceptive neuromuscular facilitation contract relax.** Technique using a maximum voluntary isometric muscle contraction followed by relaxation (Feland & Marin, 2004).

**Deep thermotherapy.** The application of modalities causing a tissue temperature rise in deeper tissues (3-4 cm) (Knight & Draper, 2008a).

**Pulsed shortwave diathermy.** A modality using high-frequency electromagnetic waves in a pulsed mode to produce thermal and non-thermal effects in deep tissue (Knight & Draper, 2008b).

**Flexibility.** Mobility of a body segment, dependent on soft tissue tolerance to movement and the ability of soft tissue to move with forces applied to it (Houglum, 2010).

**Moist heat pack.** A silicate gel pack heated to 75° to 80°C in a water hydrocollator (Roberston et al., 2005).

**Proprioceptive neuromuscular facilitation (PNF).** A combined movement pattern using neural stimulation to facilitate a proper muscle response (Houglum, 2010).

**Static stretch.** A slow stretch of a particular muscle or muscle group, held at the point of discomfort for a period of time ranging from 6 to 60 seconds (Feland et al., 2001).

**Superficial thermotherapy.** The application of modalities to the surface of the body that primarily heat the surface tissues (<1 cm) (Knight & Draper, 2008a).

### **Delimitations**

This study was delimited to college students ranging from 18-24 years of age, with 90 degrees or less of hip flexion. Participants partook in an administered 20-minute-deep heating or 15-minute superficial heating modality combined with a stretching technique, three times a week for five weeks. Flexibility of the hamstring muscles was measured via goniometry. For safety measures, all female participants could not be or suspected of being pregnant.

### **Limitations**

A limiting factor to this study was establishing an adequate sample size. Equipment used in this study was limited to what the Athletic Training Department at Fort Hays State University had in its inventory. The subject's compliance to the study

was also a major limitation. If a subject missed one session throughout the five-week study, his/her data was not included in the final results.

### **Assumptions**

Individuals did not have any hamstring pathologies. For safety reasons, individuals could not have any electrical devices, which would contraindicate diathermy application. All individuals who participated followed verbal instructions of PNF contract relax technique, ceased the static stretch when the stopwatch reached the allotted time, and had basic knowledge of the applications and stretching techniques. All information was accurately transferred and recorded. While the study was being conducted, the researcher trusted the subjects would not increase any stretching activities outside of their normal routines.

### **Null Hypothesis**

The following null hypotheses were tested:

1. Individuals participating in pulsed shortwave diathermy combined with PNF contract relax stretching showed no significant difference in pre- and post-test scores of flexibility.
2. Individuals participating in pulsed shortwave diathermy combined with static stretching showed no significant difference in pre- and post-test scores of flexibility.
3. Individuals participating in moist heat pack combined with static stretching showed no significant difference in pre- and post-test scores of flexibility.

4. Individuals participating in pulsed shortwave diathermy combined with PNF contract relax stretching versus a moist heat pack combined with static stretching showed no significant difference in post-test scores of flexibility.

5. Individuals participating in pulsed shortwave diathermy combined with PNF contract relax stretching versus pulsed shortwave diathermy combined with static stretching showed no significant difference in post-test scores of flexibility.

6. Individuals participating in pulsed shortwave diathermy combined with static stretch stretching versus a moist heat pack combined with static stretching showed no significant difference in post-test scores of flexibility.

### **Significance of Study**

The most common technique for increasing joint range of motion (ROM) is stretching (Draper, Castro, Feland, Schulthies, & Eggett, 2004). Heating modalities like warm whirlpools, moist hot packs, ultrasound and shortwave diathermy are currently used in combination with different stretching techniques to increase ROM. Flexibility has been widely observed by athletic trainers, physical therapists, rehabilitation specialists, physical educators and coaches (Bandy & Irion, 1994; Nakano et al., 2012). After athletes are injured, body parts are immobilized and shortening with resistance to stretching occur in muscles (Draper et al., 2004). Flexibility can increase sports performance, prevent injury, alleviate muscle soreness and minimize age-related loss of flexibility (Bandy & Irion, 1994; Decoster, Cleland, Altieri, & Russell, 2005; Nakano et al., 2012). “Clinicians have generally considered flexibility training to be an integral component in the prevention and rehabilitation of injuries, as well as a method of

improving one's performance in daily activities and sports" (DePino, Webright, & Arnold, 2000, p. 56). Combining stretching and heating techniques to find the optimal increase in range of motion is essential in athletics. In the athletic training clinical setting, it is vital to select the correct therapeutic intervention to obtain overall ROM increases in athletes. Increases in flexibility can help athletes recover and return to play more quickly. However, the ultimate goal is to prevent the injury from occurring.

Data from this study can be taken to college administrations to show the effect pulsed shortwave diathermy has on flexibility and how it can improve range of motion in athletes. This study can generate new research in the following two areas: different PNF stretching techniques combined with pulsed shortwave diathermy and ultrasound along with different PNF stretching techniques to improve flexibility. While researching this study, it was discovered different diathermies have varying settings. It would be interesting to perform a study examining different diathermy settings needed to achieve desired temperature changes.

## Chapter II

### REVIEW OF LITERATURE

**Introduction.** Clinicians use different types of thermo-modalities in combination with stretching techniques to achieve desired range of motion increases. It is important to understand the physiological process occurring within muscle tissue during different heating and stretching applications. This review of literature will explain the physiological effects of heat and stretching as well as go into depth about types of superficial and deep heating modalities with different stretching techniques.

**Physiological effects of heat.** Diathermy's heat production is transferred to underlying tissue through conversion. "Conversion is a process that occurs when a form of energy other than heat (electricity, chemical, mechanical, etc.) is converted to heat within the body" (Knight & Draper, 2008a, p. 192).

Moist heat packs are transferred to underlying tissue through conduction and by decreasing the thermal gradient. "Conduction is heat transfer between two objects of uneven temperatures after coming into contact with each other" (Knight & Draper, 2008a, p. 189). Conduction works at the cellular level. Conduction can only heat superficial tissues, because heat dissipates in subcutaneous tissues before it has the ability to reach deeper tissue (Knight & Draper, 2008a). In other words, as molecular temperature increases, molecules begin to vibrate and interact with cooler neighboring molecules, which results in heat transfer. As heat is being conducted from within the moist heat pack, surrounding tissue temperatures increase and the thermal gradient decreases. This process will continue until the tissue reaches equilibrium.

**Deep heat.** Clinicians have been using deep heating modalities to increase tissue extensibility, lessen nerve sensitivity, increase blood flow, increase tissue metabolism, decrease muscle spindle sensitivity to stretch, cause muscle relaxation and increase tissue flexibility (Draper et al., 1999; Hawkes et al., 2013; Peres et al., 2002; Taylor et al., 1995). “Deep thermotherapy is the application of modalities that cause a tissue temperature rise in deep tissues” (Knight & Draper, 2008a, p. 189). Past research has shown tissue temperature must increase 4° C to achieve vigorous heating of underlying structures (Hawkes et al., 2013). It is important to achieve a 4° C temperature change within the muscle tissue because this vigorous heating allows collagen-rich tissues the ability to be stretched easier.

Shortwave diathermy (SWD) is the most commonly used type of diathermy. SWD uses electromagnetic waves, much like radio waves, at a frequency of 27.12 MHz to heat deep tissues. The SWD is composed of a generator, housing for all the electrical components, and the drum, or applicator, which contains a copper coil. The generator converts alternating electrical current to a radio frequency which then passes through the drum. This radio frequency is then transmitted to the copper coil, which produces a magnetic field. As the drum is transmitting the radio frequency, an oscillating magnetic field is produced within the body causing kinetic energy in ions and molecules to increase and eddy currents to be created. This process causes thermal effects within bodily tissues (Knight & Draper 2008b).

Continuous shortwave diathermy (CSWD) uses a continuous current to treat a variety of conditions. This type of diathermy was discontinued in fighting infections

during the 1950's because the creation of antibiotics. Today, CSWD is not used very often because of the rapid heating, which can cause pain in many patients (Knight & Draper 2008b).

Pulsed shortwave diathermy (PSWD) is becoming more popular in the clinical setting due to increasing research showing positive results. PSWD has thermal or non-thermal properties depending on three factors: pulse width, pulse rate, and power. Changing each of these factors can result in different temperature changes within the body. PSWD has been used as a deep heating modality heating tissues at 3 to 5 cm and causing a 4° C temperature increase within tissues (Peres et al. 2002; Robertson et al., 2005; Garrett et al., 2000). PSWD can also provide pain relief, produce muscle relaxation, increase blood flow, increase extensibility of collagen tissue and decrease joint stiffness (Draper et al., 1999; Hawkes et al., 2013; Nakano et al., 2012; Peres et al., 2002;). Diathermy has the ability to heat larger areas of tissue compared to ultrasound making it ideal for heating large areas of muscle (Draper et al., 2002). However, it has several contraindications for use including individuals with metal implants, pacemakers, tissue burns, necrosis, acute inflammation, or thrombophlebitis (Cacolice, Scibek, & Martin, 2013; Cole & Eagleston, 1994).

Draper et al. (1999) conducted a study to measure the increase of tissue temperature during a PSWD application. During this study, tissue temperature change was measured at 3.78 degrees Celsius with a peak tissue temperature of 39.8 degrees Celsius (Draper et al., 1999). Thus, a 15 minute PSWD application can result in a 4° C temperature change within tissues. Peres et al. (2002) conducted a study measuring the



increase of dorsiflexion at the ankle. The diathermy and stretching group had the biggest increase in ROM with 7.2 degrees; whereas the heat, stretching, and ice group had an increase of 4.9 degrees. Draper et al., (2004) conducted a study to observe the changes in hamstring flexibility with a pulsed shortwave diathermy combined with a low-load, long duration stretch. After five days, mean knee extension range of motion (ROM) with the diathermy and stretch group increased 15.8 degrees compared to the sham diathermy and stretch group with a 5.2 degree increase.

**Superficial heat.** Superficial heating modalities include silicate gel (hot heat packs), whirlpool, and paraffin baths which cause temperature changes in tissues at a depth of 1 cm (Garrett et al., 2000). “Superficial thermal modalities will heat tissues deeper than 1 cm, but the amount of heating is not enough to evoke the desired therapeutic effects” (Knight & Draper, 2008a, p. 189). Past research has shown tissue temperature must increase 1° C to achieve mild heating and 2° C to 3° C for moderate heating (Hawkes et al., 2013).

Moist heat packs are most often used in the clinical setting to increase temperature at a superficial depth of 1 cm (Hawkes et al., 2013). A study by Sawyer, Uhl, Mattacola, Johnson, and Yates (2003) was conducted to determine the effects of moist heat pack on muscle flexibility and muscle temperature. There was no significant increase in hamstring flexibility when compared to the control group. Muscular temperature was increased an average of 0.4° C above baseline temperature. Hamstring flexibility in this study did not have significant increases because the application of moist heat pack did not increase muscular temperature enough to cause tissue extensibility.

Henricson et al. (1984) conducted a study on different combinations of stretching and heating on ROM at the hip joint. Superficial heat was conducted by an electrical heat pad placed on the hamstring muscle. Hip motions increased by 10 degrees in the stretching alone group, heat alone group had no increases, and the heat combined with stretching group increased hip ROM by 20 degrees.

**Physiological effects of stretching.** Every muscle in the body contains mechanoreceptors that have a stretch reflex. These mechanoreceptors are muscle spindles and Golgi tendon organs, which sense changes within the muscle. When a stretch is being applied to a muscle, muscle spindles and Golgi tendon organs detect the stretch and send sensory impulses to the spinal cord. Muscle spindles are activated during a stretch causing messages to be sent to the spinal cord, resulting in the muscle contracting providing a resistance to the stretch. The Golgi tendon organ responds to the change of tension and sends sensory impulses to the spinal cord. While the stretch is being placed, the Golgi tendon organ starts to override the muscle resulting in the relaxation of the stretched muscle. “This reflex relaxation serves as a protective mechanism that will allow the muscle to stretch through relaxation without exceeding the extensibility limits, which could damage the muscle fibers” (Prentice, 2011, p, 180). This is known as autogenic inhibition. However, reciprocal inhibition can also occur, which is a contraction of the opposing muscle and reduces the contraction of target muscle allowing the muscle to lengthen (Sharman, Cresswell, & Riek, 2006; Yuktasir & Kaya, 2009).

**Stretching.** Coaches, athletic trainers, and other therapists have used stretching to restore muscle flexibility, prevent injury, maximize sports performance, regain ROM and

alleviate muscle soreness (Feland et al., 2001; Miyahara et al., 2013; Nakano et al., 2012).

Widely debated among researchers has been the time, duration and magnitude of stretching required to achieve improved flexibility. Also, the most effective types of techniques are debatable such as static and PNF stretching.

Heat combined with stretching has shown to increase flexibility and restore range of motion (Draper et al., 2005; Henricson et al., 1984; Nakano et al., 2012). “Increasing the temperature has a positive effect on the ability of the collagen and elastin components within the musculotendinous unit to deform” (Prentice, 2011, p. 180).

Static stretching is a widely used technique that can be applied actively or passively. During static stretching, muscles are slowly lengthened until an individual has a comfortable stretch sensation and is held for a period of time (Bandy & Irion, 1994). A study performed by Bandy and Irion (1994) concluded a static stretch held for 30 and 60 seconds had greater ROM increases than holding a static stretch for 15 seconds.

Proprioceptive neuromuscular facilitation was first used in the 1940’s by neurologists to treat patients with paralysis, spasticity, and weakness (Sharman et al., 2006; Knortz & Ringel, 1985). PNF is used in the clinical setting mainly to increase active and passive range of motion (Maddigan, Peach, & Behm, 2012; Sharman et al., 2006; Victoria et al., 2013). PNF is considered the most effective stretching technique to increase ROM (Sharman et al., 2006; Victoria et al., 2013). PNF can also be utilized to increase flexibility, muscular strength and endurance, joint neuromuscular control, and improve joint stability (Victoria et al., 2013). PNF movements occur in spiral and

diagonal planes, allowing for more coordinated movements (Sharman et al., 2006; Victorria et al., 2013).

There are two patterns used in PNF stretching: agonist and antagonist. The agonistic pattern occurs while the muscle is shortening; whereas, the antagonistic pattern occurs when the muscle is elongating. Using the hamstring muscle as an example, a PNF contract relax stretching technique would occur as follows:

With the patient's knee and hip placed at the end-range (knee extension and hip flexion) in the agonistic (quadriceps and iliopsoas) pattern, the clinician provides isotonic resistance against the antagonist muscles (hamstring) to allow diagonal and rotational motion to the end range (knee flexion and hip extension with hip rotation). When the patient relaxes the muscle, the clinician moves the part passively into the agonistic muscle pattern to stretch the antagonist (hamstrings).

The process is repeated several times. (Houglum, 2010, p. 144)

There are two other types of PNF techniques that improve flexibility: hold-relax and slow reversal hold-relax. The hold-relax method is primarily used to relax muscle spasms. The slow reversal hold-relax method is used to improve range of motion, but is more complicated to perform.

### **Summary**

A preponderance of research documents the effectiveness of using heat in various applications in treatment of the human musculoskeletal system. One of the major concerns in athletic training is in the treatment of injuries that occur as a result of decreased range of motion in the major large muscle groups (i.e., hamstring group).

Reduced joint range of motion due to flexibility issues can be influenced by many factors such as poor posture, injury and muscle soreness, as well as general inactivity. Athletic trainers, coaches, and other physical rehabilitation therapists have historically used different stretching techniques and heating applications to increase or regain ROM through muscle flexibility. Previous research has shown stretching to increase joint ROM providing assistance in preventing injuries, regaining ROM, and alleviating muscle soreness.

A major problem in treating decreased ROM has been the ability to transfer the thermo-modality deep into large muscle groups such as the hamstrings. Pulsed shortwave diathermy application is designed to penetrate more deeply into tissues and covers a larger treatment area than other types of thermo-modalities. Deep heating muscle tissues causes increased metabolism and tissue extensibility, which allows collagen fibers to stretch. Deep heating modalities when combined with different stretching techniques have greater increases in range of motion than just heat alone. Through the application of the process outlined in this paper, the effects of pulsed shortwave diathermy combined with a specific stretching protocols on hamstring flexibility will be established and compared with other traditional methods of thermal-modalities.

## Chapter 3

### METHODOLOGY

**Introduction.** The purpose of this study was to investigate the effect of pulsed shortwave diathermy combined with static stretching versus pulsed shortwave diathermy combined with proprioceptive neuromuscular facilitation (PNF) contract relax stretching versus moist heat pack combined with static stretching on hamstring flexibility.

Preliminary and operational procedures were used to further investigate the problem of this study. The purpose of the preliminary procedures were used to organize the study while the purpose of the operational procedures were used to give details on how the study conducted. Preliminary procedures included were selection of subjects, instruction for subjects, selection of instrumentation, selection of research design, and selection of statistical design. Operational procedures included were instrument administration and data collection.

#### **Preliminary Procedures.**

***Selection of subjects.*** Subjects used for this study included college students (both male and female) ranging in age from 18 to 24 years. No female volunteers in the study could be or suspected to be pregnant. Volunteers from the following Health and Human Performance (HHP) classes were given an open invitation by their professors to participate, followed by a description of the study from the informed consent document: Athletic Training Program ATEP 310, 400, and 470, HHP 447 Instrumentation in Exercise Physiology, and HHP 390 Physiology of Exercise. All students in the above mentioned classes were required to participate in a number of pre-professional

experiences related to research. Students who wished to participate in the study were given a consent to participate in research study form (see Appendix A) and a debriefing statement (see Appendix B) to sign. Any athletes who wished to participate in the study were instructed to cease any activity one and half hours prior to partaking in the study. This insured the muscles were not in an elastic state. Volunteers had the option of picking which leg they wanted tested. However, if they reported previous hamstring injuries their contralateral leg was used in the study. Volunteers were chosen based on their hamstring flexibility measured via a goniometer. If their measurement was 90 degrees or less, they qualified for the study. Volunteers were also chosen based on class and work schedule. Qualifying students were given a demographic questionnaire (see Appendix C) and non-pregnancy form (see Appendix D) to complete. A minimum of thirty volunteers were randomly assigned to a pulsed shortwave diathermy/PNF contract relax stretching group, a pulsed shortwave diathermy/static stretching group, or a moist heat pack/static stretching group. Two additional subjects were tested to replace non-compliant subjects in the PSWD/static stretching group and the PSWD/PNF contract relax stretching group. Institutional review board approval (see Appendix E) was obtained before any participants started the study.

***Instruction for subjects.*** All subjects read a short study description and signed an informed consent form before beginning the study. They were instructed to ask the researcher questions regarding the study prior to the beginning of testing. Subjects were requested not to increase any stretching activities outside their normal routines while the study was being conducted and were also informed they could stop at any time during the

study for any reason. Subjects were given their measurements only after the last session. This inhibited a competitive tendency. Each subject was asked to report to the Athletic Training lab three days a week for a five-week period. Participants signed up for times throughout the week with a 36 hour lapse between sessions.

***Selection of instrumentation.*** The study was conducted in the Athletic Training Lab located in Cunningham Hall at Fort Hays State University. An Intellect SWD 100 pulsed shortwave diathermy machine with a 27.12 MHz operating frequency was used as a deep thermotherapy modality. The pulsed shortwave diathermy machine had the following parameters: 800 bursts per second, 400-microsecond burst duration, and an average root-mean-square output of 48 Watts per burst. Only the research assistants who completed ATEP 330 Therapeutic Exercise I, which taught the proper techniques and verbal commands effectively, conducted the PNF contract-relax stretching protocol. The PNF contract relax stretching technique was conducted as follows: the subject was placed in a passive hamstring stretch for ten seconds, followed by a concentric contraction of the hamstring muscles through the full range of motion, followed by a further passive stretch. This technique was repeated five times. A stopwatch was also used during moist heat pack treatments, static stretching, relax phase of static stretching, and the relax phase of the PNF stretch to notify the researcher and subject as to when to cease the treatments. A stopwatch was used to keep the time of each modality treatment.

Hamstring flexibility was measured via hip flexion using the passive straight leg raise test. The passive straight leg test was conducted by: placing the subject supine with the contralateral leg secured to the treatment table with a hook-and-loop fastener strap



across the middle of the thigh (see Figure 1). This was followed by one research assistant placing the subject into a passive hip flexion position with the knee fully extended to place a stretch on the hamstring muscles. The other research assistant simultaneously placed and read the goniometer measurement (Clarkson, 2005) (see Appendix F for passive straight leg raise for goniometer measurement). The research assistants were aware to prevent any hip rotation, lifting of the contralateral leg, or bending of the ipsilateral knee. The subjects were instructed to keep their ankles in a relaxed plantar flexion position to inhibit neural tension (Clarkson, 2005; Davis, Quinn, Whiteman, Williams, & Young, 2008). Hamstring flexibility was assessed using a universal goniometer. Gogia, Braatz, Rose, & Norton (1987) conducted a study on the reliability and validity of a universal goniometer for knee measurements. They found the goniometer was both reliable ( $r = 0.98$ ) and valid ( $r = 0.97-0.98$ ). Figure 2 illustrates the correct placement of the goniometer.

***Selection of research design.*** This study was designed to investigate the effect of pulsed shortwave diathermy combined with static stretching versus pulsed shortwave diathermy combined with proprioceptive neuromuscular facilitation (PNF) contract relax stretching versus moist heat pack combined with static stretching on hamstring flexibility. The independent variables include pulsed shortwave diathermy, moist heat pack, PNF contract relax stretching technique, and static stretching. The dependent variable was the measurement of hip flexion via a goniometer. This study used a pre- and post-test randomized groups design. Subjects were randomly assigned into a group with hamstring range of motion assessed pre- and post-test treatments. Each subject's post-test value was

subtracted from his/her pre-test value and the difference was analyzed as the change in degrees of flexibility.

***Selection of statistical design.*** All statistical analyses were performed using PHStat® and Excel® software. For each group, means for the pre- and post-test measurements were calculated, as well as the mean differences for hamstring flexibility measured via hip flexion range of motion in degrees. A paired *t*-test was used to determine whether a significant difference existed between the initial and final measurements of each group. A separate-variance *t*-test was used to determine whether a significant difference existed between groups. All data were analyzed at the .05 level of significance.

### **Operational Procedures**

***Test administration.*** Thirty subjects were randomly assigned to three groups; PSWD combined with static stretching group, PSWD combined with PNF contract relax stretching group, and moist heat pack combined with static stretching group.

Subjects in the pulsed shortwave diathermy combined with static stretching group were first placed supine on a treatment table to acquire a pre-test goniometer measurement. Subjects were then placed prone on the treatment table with the head of the PSWD placed in the center of their hamstring muscles (see Figure 3 on PSWD set up). The PSWD treatment lasted twenty minutes and had the following parameters to achieve a 4° C temperature change: 800 bursts per second, 400-microsecond burst duration, and an average root-mean-square output of 48 watts (W) per burst. After the PSWD treatment, a static stretch was performed on the treatment leg. Subjects were placed supine on the

table and their contralateral leg placed flat on the table. It was then secured with a hook-and-loop fastener strap across the middle of the thigh. This was followed by the investigator placing a static stretch on the hamstring muscles of the treatment leg until a good quality but painless stretching sensation was felt. This provided a constant stretch over three sets of thirty second hold duration with twenty seconds of rest between sets. The subjects were not allowed to have any hip rotation, lifting of the contralateral leg, or bending of the ipsilateral knee. After the static stretch was completed, the post-test goniometer measurement was acquired.

Subjects in the PSWD/PNF contract relax stretching group were placed supine to acquire a pre-test goniometer measurement. Subjects receiving a PSWD treatment in group two had the same protocol as group one. After the PSWD treatment was conducted, a PNF contract relax stretching technique was performed on the treatment leg. Subjects were placed supine on the table and their contralateral leg placed flat on the table and secured with a hook-and-loop fastener strap across the middle of the thigh. The PNF contract relax technique required the test leg placed in a passive hamstring stretch for ten seconds. This was then followed by the subjects extending the hip using a concentric contraction of the hamstring muscles through the full range of motion. The concentric contraction was then followed by a further passive stretch for ten seconds. This stretching cycle was repeated five times. The subject communicated with the investigator when a high-quality stretch was felt without pain. After the PNF contract relax stretching technique was completed, the post-test goniometer measurement of hip flexion was acquired.

Subjects in the moist heat pack/static stretching had a pre-test goniometer reading of hip flexion taken while supine on a table. Subjects were then placed prone on a treatment table while a terry clothed moist heat pack was applied to the middle of the hamstring muscle with a five-pound weight placed on top of the moist heat pack. If a subject stated the heat pack was too hot, a towel was placed under the terry cloth for comfort. After a fifteen-minute moist heat pack session was conducted, static stretching was performed. Subjects received the same static stretching technique as group one. After the static stretching was completed, the post-test goniometer measurement of hip flexion was acquired.

**Data collection.** Goniometer measurements were used to determine hamstring flexibility via hip flexion using the passive straight leg raise test. The anatomical landmarks for the goniometer were as follows: axis was placed on the greater trochanter, stationary arm was parallel to the trunk, and the moveable arm was parallel to the femur. The passive straight leg test was performed by placing the subject supine with the contralateral leg secured to the treatment table with a hook-and-loop fastener strap. This was followed by one research assistant placing the subject into a passive hip flexion position with the knee fully extended to place a stretch on the hamstring muscles. The other research assistant then placed and read the hip flexion goniometer measurement (Clarkson, 2005). The research assistants were aware of any hip rotation, lifting of the contralateral leg, or bending of the ipsilateral knee. Subjects were instructed to keep their ankle in a relaxed plantar flexion position to inhibit neural tension (Clarkson, 2005; Davis

et al., 2008). Data were collected and recorded on the subject's data chart before and after each treatment session.

## Chapter 4

### RESULTS

Thirty-two college students with limited hip flexion participated in this study. Two participants were disqualified from the study due to lack of compliance. Two additional subjects were tested to replace non-compliant subjects in the PSWD/static stretching group and the PSWD/PNF contract relax stretching group. This left thirty participants (male,  $n = 18$ ; female,  $n = 12$ ; mean age, 20.3 years). Table 1 shows other participant demographics.

**Table 1.**

***Participant Demographics***

	n	Average Age	Left Leg	Right Leg	Average ROM Initial Mean	Average ROM Increase	Days/Week stretch Average	Minutes/Day Stretch Average
<b>Male</b>	18	20.22	7	11	67.17°	27.00°	2.56	7.78
<b>Female</b>	12	20.5	7	5	69.67°	34.42°	2.25	10
<b>Participant demographics split between male and female</b>								

A paired  $t$  test was used in all analyses of pre- and post-test scores of flexibility of individual groups at the  $p=.05$  level of significance. Table 2 shows the  $t$ -scores and calculated  $p$ -value for individual groups. The mean and standard deviation of individual groups are as shown in Table 3.

**Table 2.**

***t-score and p-value for individual groups***

	<b><i>t-scores</i></b>	<b><i>p-value</i></b>
<b>PSWD/PNF contract relax</b>	13.5171	<.001*
<b>PSWD/static stretch</b>	12.2241	<.001*
<b>Moist heat pack/static stretch</b>	6.4398	.0001*
<b><i>t-score and calculated p-value for each research group of pre- and post-test measurements</i></b>		
<b>*Significant difference (<math>p&lt;.05</math>)</b>		

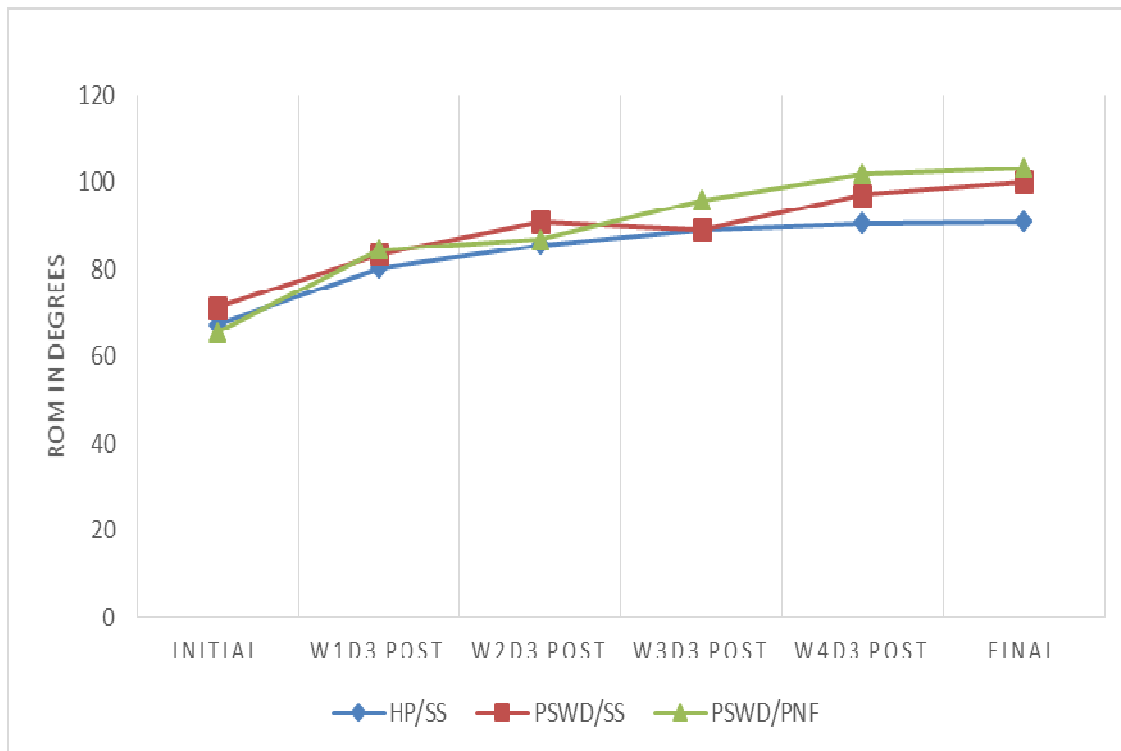
**Table 3.**  
***Mean and Standard Deviation of Individual Group Comparisons***

	<b>PSWD Combined with PNF Contract Relax Stretching</b>	<b>PSWD Combined with Static Stretching</b>	<b>Moist Heat Pack Combined with Static Stretching</b>
<b>Initial Measurement</b>	65.7 ± 9.81	71.4 ± 8.42	67.4 ± 7.68
<b>Final Measurement</b>	103.4 ± 15.25*	100.7 ± 6.77*	90.9 ± 10.26*
<b>Means ± SD in degrees of hip flexion of motion (n = 10 in each group)</b>			
<b>*Significantly greater than initial measurement (<math>p &lt; .05</math>)</b>			

A significant difference ( $t=13.5171$ ,  $p<.001$ ) was found in pre- and post-test scores of flexibility in the PSWD combined with PNF contract relax stretching group indicating the rejection of the first null hypothesis. This group had an initial mean of 65.7° with a standard deviation of 9.81° and final mean of 103.4° with a standard deviation of 15.25°. A significant difference ( $t=12.2241$ ,  $p<.001$ ) was found in pre- and post-test scores of flexibility in the PSWD combined with static stretching group indicating the rejection of the second null hypothesis. This group had an initial mean of 71.4° with a standard deviation of 8.42° and final mean of 100.7° with a standard deviation of 6.77°. A significant difference ( $t=6.4398$ ,  $p=.0001$ ) was found in pre- and post-test scores of flexibility in the moist heat pack combined static stretching group indicating the rejection of the third null hypothesis. This group had an initial mean of 67.4° with a standard deviation of 7.68° and final mean of 90.9° with a standard deviation of 10.26°.

The average increase in weekly range of motion for each group is represented in Figure 1. This demonstrates the PSWD/PNF contract relax stretching group had the greatest increase in flexibility over the five-week period. This was followed by the

PSWD/SS group with the moist heat pack combined with static stretching group resulting in the least amount of flexibility increase.



*Figure 1.* The average of the initial, last day of each week and final measurement were calculated to obtain the average increase per week. The triangle line represents the PSWD/PNF contract relax stretching group, which has the greatest increase in range of motion. Followed by the square line representing the PSWD/SS and lastly the diamond line, which represents the moist heat pack combined with static stretching group.

Table 4 shows the  $t$ -scores and calculated  $p$ -values for comparison between groups. A separate-variance  $t$ -test was used in all analyses of post- test scores of flexibility between groups at the  $p=.05$  level of significance. A significant difference ( $t=2.4687, p=.0122$ ) was found in post-test scores of flexibility between the PSWD combined with PNF contract relax stretching group and the PSWD combined with static



stretching group indicating the rejection of the fourth null hypothesis. A significant difference ( $t=3.0917$ ,  $p=.0035$ ) was found in post-test scores of flexibility between the PSWD combined with PNF contract relax stretching group and the moist heat pack combined with static stretching group indicating the rejection of the fifth null hypothesis. No significant difference ( $t=1.1984$ ,  $p=.1247$ ) was found in post-test scores of flexibility between the PSWD combined with static stretching group and the moist heat pack combined with static stretching group indicating the acceptance of the sixth null hypothesis.

**Table 4.**  
*t-score and p-value for comparison between groups*

	<i>t-scores</i>	<i>p-value</i>
<b>PSWD/PNF contract relax versus PSWD/static stretch</b>	2.4687	.0122*
<b>PSWD/PNF contract relax versus Moist heat pack/static stretch</b>	3.0917	.0035*
<b>PSWD/static stretch versus Moist heat pack/static stretch</b>	1.1984	.1247

*t*-score and calculated *p*-value for comparison of each groups post-test measurements

\*Significant difference ( $p<.05$ )

## **Chapter 5**

### **DISCUSSION**

This study found all three groups had a significant increase in hamstring flexibility from pre-test to post-test measures. However, the moist heat pack combined with static stretching group had less of an increase compared to the other two groups. Previous studies conducted by Henricson et al. (1984), Sawyer et al. (2003), and Taylor et al. (1995) concluded there was not a significant increase in range of motion when superficial heating modalities were used in combination with static stretching. The significant difference found in this study may have been due to the five weeks over which the study was conducted compared to the short duration previous studies examined. It cannot be determined from the current study if the significant difference was produced from the moist heat pack application or the static stretching.

Studies conducted by Draper et al. (2004) and Peres et al. (2002) have shown pulsed shortwave diathermy in combination with prolonged static stretching significantly increases range of motion more than prolonged static stretching alone. This study determined a significant increase was found in the PSWD combined with static stretching group. In order to sustain maximum range of motion results, static stretching should be combined with PSWD rather than performed alone.

A study conducted by Varilek (2008) determined there was no difference in range of motion increases between groups using PSWD combined with different PNF stretching techniques when compared to using PNF stretching techniques alone. This study was conducted over the course of seven days. However, the study did find the

greatest increase in range of motion occurred when PSWD was combined with PNF contract relax stretching and PNF hold relax techniques. Again, it cannot be determined if the significant increase in the PSWD combined with PNF contract relax stretching group was produced from the PSWD or the PNF contract relax stretching technique.

No previous studies have examined post-test scores of flexibility between the three different treatment groups used in this study. However, comparing the post-test scores between groups can show which group has the most significant difference. PSWD combined with static stretching and moist heat pack combined with static stretching did not have a significant difference between post-test scores of flexibility. Although no significant difference was found, this group was approaching significance ( $p=.1245$ ). With a larger sample group, it can be speculated there would be a significant difference.

PSWD combined with PNF contract relax stretching and moist heat pack combined with static stretching had a significant difference between post-test scores of flexibility. These results occurred for several reasons. First, PSWD is able to heat muscle tissues three to five centimeters deep and increase the temperature 4°C. This is theorized to cause tissue extensibility, unlike the moist heat pack, which is only heating tissues at a depth of one centimeter. This is not deep enough to change the muscle tissue temperature. Second, previous studies conducted by Feland et al. (2001) and Yuktasir and Kaya (2009) found significant differences in range of motion with both PNF stretching exercises and static stretching. However, PNF stretching exercises showed significantly greater improvements. Combining these results indicates a deep heating modality followed by a PNF stretching technique can increase range of motion significantly more than moist heat

pack combined with static stretching. It is also reasonable, based on data from this study and others cited, that PSWD combined with PNF contract relax increases flexibility and greater ROM then PSWD and static stretching.

### **Future Research**

One major limitation of this study was a small population. If time constraints were not an issue a bigger sample size would have been used. Having a larger sample size would also allow the addition of more treatment groups to the study such as moist heat pack combined with PNF contract-relax stretching, static stretching alone and PNF contract-relax stretching alone. With the data collected and compared from these groups, a determination if range of motion increases are specifically due to heating modalities or stretching techniques could be made.

Another factor needing more research is examining the amount of resistance applied during the concentric phase of the PNF contract-relax stretching technique. Throughout this study, different research assistants with different muscular strength conducted the PNF contract relax technique. Some participants stated increases in range of motion did not occur because there was a lack of resistance applied by the research assistants. A pulley system would be a very affective apparatus to insure equal resistance based on body weight is given throughout the study.

Another area of research needed is observing plateau effects of each treatment group. This could give clinicians information about how long it takes athletes to improve to their maximum range of motion. This would give clinicians a time frame in which the known increase in flexibility could be achieved with the techniques.

Diathermy machines are becoming more popular in the clinical setting. However, not all manufactures produce diathermies to achieve a 4° temperature change. Research conducting continuous wave diathermy using different settings to achieve temperature change within tissues would be advantageous to clinics having already purchased an expensive diathermy machine and benefit patients in reaching their rehabilitation goals.

### **Summary**

When applying these results to the athletic training clinical setting, this study shows PSWD combine with PNF contract relax stretching is one of the most effective ways to increase hamstring flexibility. With lack of time, resources and staff, athletic trainers will often apply a moist heat pack to the patient for fifteen minutes followed by static stretching. This approach can show limited benefits for patients. However, this study demonstrated this is the least effective way to produce maximum flexibility results. If clinicians are going to use a PNF stretching technique, it is in their best interest to combine it with a PSWD protocol to ensure tissue extensibility as well.

Many junior colleges and small universities may feel the purchase of a pulsed shortwave diathermy unit is cost prohibitive. However, studies seem to suggest its benefits are advantageous in relation to costs. This study found significant increases in range of motion of the hamstring muscles when pulsed shortwave diathermy was used. This increased hamstring flexibility could help reduce injuries to those patients with functional hip flexion limitations.

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Figure 2

Hook-and-Loop Fastener Strap Placement

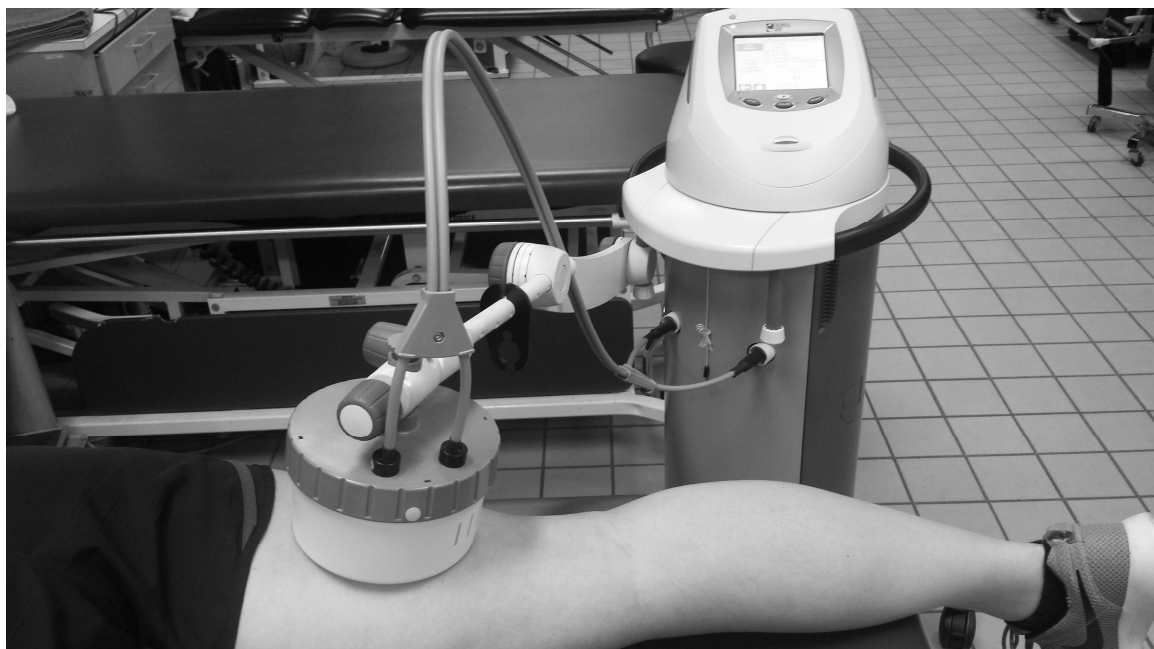


Figure 3  
Goniometer Placement



Figure 4

Pulsed Shortwave Diathermy Placement





## Appendix A

### Consent to Participate in Research

## **CONSENT TO PARTICIPATE IN RESEARCH**

You are being asked to participate in a researcher study called “The effect of diathermy combined with different stretching techniques versus superficial heat combined with proprioceptive neuromuscular facilitation (PNF) contract relax on hamstring flexibility.” You have the decision to participate or not. This study is conducted by Amee Stapleton and Dr. David Fitzhugh from the Health and Human Performance Department at Fort Hays State University. This research project is currently being conducted as part of my thesis for my Master’s Degree.

Please read the information below and ask any questions you have, before deciding to participate.

### **Purpose of the Study**

Athletic trainers have been treating tight hamstring muscles with moist heat packs, a superficial heating modality, combined with static stretching. Moist heat packs are more cost effective than diathermy. This study will look at the effects of a diathermy, which is a deep heating modality accompanied with different stretching techniques. Will the more expensive modality alleviate tight hamstring muscles and possibly decrease number of injuries?

### **Procedures**

It has been determined you have 90 degrees or less of hip flexion. If you decide to participate in this research study, you will be asked to sign this consent form after you have had all your questions answered and understand what will occur during the study. You will be asked to report to the Athletic Training Lab located in Cunningham Hall room 147B at Fort Hays State University, twice a week for eight weeks. Approximately 30 participants will be in this study. If you choose to participate for this study the following procedures will be followed: you will be randomly placed in one of three groups. The first group will include a diathermy protocol for 20 minutes and 3 x 30 seconds static stretch. The second group will include a diathermy protocol for 20 minutes and a PNF contract relax protocol. The third group will include a moist heat pack application of 20 minutes and a PNF contract relax protocol. You will need to sign up for time slots that work for your schedule and report on time. You will also need to adhere to the researcher(s) directions and give full effort during the study.

### **Potential Risks and Discomforts**

It is unlikely you will suffer any harm participating in this project. But there are some minimal risks, which include the following: skin burns from the diathermy, mild shocks from the diathermy (if the volunteer is using electrical devices, which they are advised not to do), uncomfortable stretching sensation, diathermy can cause harm to a fetus (any females that are pregnant or have reason to believe they are pregnant are excluded from

the study). The researchers have been properly trained and educated on the uses and the science and safety behind the use of a diathermy and how to correctly use PNF techniques to minimize the potential risks.

### **Potential Benefits to Participants and/or to Society**

Volunteers needing pre-professional experience for class can gain hours through this research study. Volunteers from the Athletic Training Program (ATP) can gain further knowledge about diathermy and different stretching techniques. The ATP students will not get this experience in the clinical setting and can be used as a teaching moment.

### **Confidentiality**

Information identified about you obtained in connection with this study will remain confidential and will only be disclosed with your permission or as required by law. Confidentiality will be maintained by assigning each volunteer a group and number chosen at random by the researcher. The results of this study will be used and possibly published in a scientific journal. However, all personal information will be removed and only actual data collected will be represented.

### **Participation and Withdrawal**

You can choose whether or not to volunteer to be in this study. You may withdraw from this study at any time without consequences or loss of benefits to which you are entitled. You can refuse to answer any questions you do not wish to answer. The researcher(s) may withdraw you from this research if circumstances arise which warrant doing so including if you stop reporting to treatments, do not wish to answer the pregnancy question, or stop abiding to instructions given by the researcher(s).

### **Identification of Investigators**

If you have any questions or concerns about this research, please contact:  
Amea Stapleton – Lead researcher – 580-829-2107, [ajstapleton@mail.fhsu.edu](mailto:ajstapleton@mail.fhsu.edu)  
David Fitzhugh, PhD – Faculty Advisory – 785-628-4354, [dkfitzhugh@fhsu.edu](mailto:dkfitzhugh@fhsu.edu)

### **Rights of Research Subjects**

The Fort Hays State University Institutional Review Board has reviewed my request to conduct this project. If you have any concerns about your rights in this study, please contact Dr. Greg Kandt of the Fort Hays state University HHP-IRB at e-mail [gkandt@fhsu.edu](mailto:gkandt@fhsu.edu) or Leslie Paige of the Fort Hays State University IRB at [lp Paige@fhsu.edu](mailto:lp Paige@fhsu.edu).

## CONSENT TO PARTICIPATE IN RESEARCH STUDY

I have read the above information about “The effect of diathermy combined with different stretching techniques versus superficial heat combined with proprioceptive neuromuscular facilitation (PNF) contract relax on hamstring flexibility” and have been given an opportunity to ask questions and received answers to those questions to my satisfaction. I also agree I have been thoroughly advised as to the risks associated with this research project. By signing this document, I have made an informed decision and agree to participate in this study. I have been given a copy of this consent document for my own records. I understand I can change my mind and withdraw my consent at any time. By signing this consent form, I understand I am not giving up any legal rights. I also confirm I am 18 years or older and if female, have no reason to believe I am pregnant.

---

Printed Name of Subject

---

Signature of Subject

---

Date

## Appendix B

### Debriefing

## Debriefing

Athletic trainers have been treating tight hamstring muscles with moist heat packs, a superficial heating modality, combined with static stretching. Moist heat packs are more cost effective than a diathermy. This study will look at the effects of a diathermy, a deep heating modality, accompanied with different stretching techniques to increase hamstring flexibility. Will the more expensive modality alleviate tight hamstring muscles and possibly decrease number of injuries?

If any questions or concerns arise about the study you participated in, please feel free to contact Dr. David Fitzhugh at [dkfizhugh@fhsu.edu](mailto:dkfizhugh@fhsu.edu) or 785-628-4354 or Ameer Stapleton at [ajstapleton@mail.fhsu.edu](mailto:ajstapleton@mail.fhsu.edu) or 580-829-2107. If you have any concerns about your rights in this study, please contact Dr. Greg Kandt of the Fort Hays State University HHP-IRB at [gkandt@fhsu.edu](mailto:gkandt@fhsu.edu) or Leslie Paige of the Fort Hays State University IRB at [lp Paige@fhsu.edu](mailto:lp Paige@fhsu.edu). Although we do not expect participants in this study to suffer any discomfort or anxiety, if you feel distressed after completing the study, please contact the Kelly Center at (785) 628-4401. The Kelly Center provides free counseling service to all FHSU students.

Thank you again for participating, it is greatly appreciated.

## Appendix C

### Demographic Questionnaire

## Demographic Questionnaire

**Gender:**\_\_\_\_\_ Male      \_\_\_\_\_ Female

**Age:** \_\_\_\_\_

**How many days a week do you exercise and for how long? (circle one)**

None    1 Day    2 Days    3 Days    4 Days    5 Days    6 Days    7 Days

15-30mins    30-45mins    45-60mins    60-90mins    More then 90mins

**How many times a week do you stretch and for how long? (circle one)**

None    1 Day    2 Days    3 Days    4 Days    5 Days    6 Days    7 Days

10mins    20mins    30mins    40mins    50mins    60mins

**Have you had any hamstring injuries? If so, which hamstring and when did it occur?**

---

**Do you have any low back pain or tightness?** \_\_\_\_\_ Yes \_\_\_\_\_ No

**Do you have a pacemaker?** \_\_\_\_\_ Yes \_\_\_\_\_ No

### **Females Only:**

**Is there any chance you are pregnant?** \_\_\_\_\_ Yes \_\_\_\_\_ No



## Appendix D

### Non-Pregnancy Verification Form

## **Non-Pregnancy Verification Form**

This form verifies that I, \_\_\_\_\_, believe I am not pregnant at the time of this research study and I give consent to receive diathermy treatments. If I become pregnant at any time during the study, I will withdraw myself from participation immediately. I understand the possible risks that are associated with receiving diathermy treatments while being pregnant.

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

## Appendix E

### Institutional Review Board (IRB) Approval



# FORT HAYS STATE UNIVERSITY

*Forward thinking. World ready.*

OFFICE OF SCHOLARSHIP AND SPONSORED PROJECTS

DATE: June 30, 2015

TO: Amee Stapleton, Bachelors of Science in Athletic Training  
FROM: Fort Hays State University IRB

STUDY TITLE: [727587-2] The effect of diathermy combined with different stretching techniques versus superficial heat combined with proprioceptive neuromuscular facilitation (PNF) Contract-Relax on hamstring flexibility

IRB REFERENCE #: 15-047  
SUBMISSION TYPE: Amendment/Modification

ACTION: APPROVED  
APPROVAL DATE: June 30, 2015  
EXPIRATION DATE: March 8, 2016  
REVIEW TYPE: Expedited Review

Thank you for your submission of Amendment/Modification materials for this research study. Fort Hays State University IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form unless documentation of consent has been waived by the IRB. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document. The IRB-approved consent document must be used.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All FDA and sponsor reporting requirements should also be followed. Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office. Please note that all research records must be retained for a minimum of three years.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact Leslie Paige at 785-628-4349 or [lp Paige@fhsu.edu](mailto:lp Paige@fhsu.edu). Please include your study title and reference number in all correspondence with this office.

## Appendix F

Passive straight leg raise for goniometer measurement

Hamstring flexibility was measured via hip flexion using the passive straight leg raise test. Passive straight leg test was conducted as follows: subjects were placed supine with the contralateral leg secured to the treatment table with a hook-and-loop fastener strap across the middle of the thigh. Then one research assistant placed their ipsilateral hip into a passive hip flexion position with the knee fully extended to place a stretch on the hamstring muscles. This was followed by another research assistant placing and reading the goniometer measurement (Clarkson, 2005). The research assistants were aware and corrected any hip rotation, lifting of the contralateral leg, or bending of the ipsilateral knee. Subjects were instructed to keep their ankle in a relaxed plantar flexion position to inhibit neural tension (Clarkson, 2005; Davis et al., 2008).